Heritability studies in tomato (*Lycopersicon esculentum* L.) genotypes

Abstract

Genetic variability, heritability, and genetic advance for fruit yield and quality traits in tomato (*Solanumlycopersicum* L.) were examined at Main Vegetable Research Station (MVRS) of Anand Agricultural University, Anand, for the kharif-rabi season of 2022-23. The experimental material is made-up of six families developed for generation mean analysis from nine diverse parents viz., 2012/TODVAR-1, AVTOV 1007, GAT-5, 2015/TOLCV RES-1, 2014/TOOV-10, 2016/TOV-10, 2017/TOLV-4, and 2015/2016/TOLCV RES-4. The results show that family I, II, III, and family V exhibited higher values of broad sense heritability with higher genetic advance, was a positive indication of presence of additive gene action and suggests selection methods for improvement of this trait via selection procedures. Higher values of genetic advance were reported highest for lycopene content (452.67 %) for family I and (212.85%) for family III, 1000 seed weight for family V. This study suggests that improvement of yield and associated traits in *L. esculentum*should be focused on character basis and requirement of breeding programs.

Keywords:

Gene action, Gene advance, Heritability, *Lycopersicon esculentum* L., Tomato

Introduction

Tomato, a member of nightshade (solanaceae) family iscultivated globally due to its wider adaptability, higher yield potential, and superior processing capabilities. It is widely cultivated in different ranges of environments, including tropical, sub-tropical, and climatic regions. The cultivated tomato and its wild relatives are supposed to came from Peruvian and adjoining regions of South America. *S. lycopersicum* var. *cerasiforme* would have shifted to Mesoamerica, where it was domesticated to *S. lycopersicum* var. *lycopersicum*. Many typical traits of cultivated tomatoes are believed to arose in South America (Nicolás *et al.*, 2020).Tomatoes, both fresh and processed, are the most abundant sources of lycopene - a highly effective antioxidant. This antioxidant has been proven to protect cells from carcinogenic oxidants (Rao and Rao, 2007).

For any successful breeding programme, information of transmission of characters and heritability to the offspring is very crucial. As yield and associated traits are not simply inherited, the study of inheritance of these traits is much necessary. Information on extant of phenotypic and genotypic variation and influence of environment in governing traits will sound basis for selection. Genetic advance is another parameter on which effectiveness of selection depends. Effectiveness of selection also depends on genetic advance. Therefore, to examine these aspects, a research study was conducted at the Main Vegetable Research Station (MVRS) of Anand Agricultural University, Anand for the *kharif-rabi* season of 2022-23.

Material and Methods

The experimental material is made-up of six families, that hasdeveloped for generation mean analysis from nine diverse parents viz., 2012/TODVAR-1, AVTOV 1007, GAT-5, 2015/TOLCV RES-1, 2014/TODVAR-5, AVTOV 1002, 2016/TODVAR-12, AVTOV 1005, 2017/TODVAR-8 and 2015/TOLCV RES-4. The experimental material was sown in Compact Family Block Design (CFBD). Five plants from P_1 (Parent 1), P_2(Parent 2) and F_1 generation were randomly selected and observations were recorded, along with ten plants from B_1(Backcross 1)and B_2(Backcross 2)generation and twenty plants from F_2 generation.

1) Heritability in broad sense: Burton (1951)'s formula was used to calculate it and expressed in percent. It is expressed as low (< 20 %), moderate (20 to 50 %) and high (> 50 %) as suggested by Johnson *et al*. (1955).

2) Heritability in Narrow Sense:From the estimates of basic generations, it was calculated by using formula as suggested by Warner (1952). It was classified as low (5-10 %), moderate (5 to 10 %) and high (> 30 %) as suggested by Robinson *et al*. (1966).

3) Genetic Advanceis Expected genetic advance under selection was estimated by using formula suggested by Allard (1960).It is expressed as low (< 10 %), moderate (10 to 20 %) and high (> 20 %) as suggested by Johnson *et al*. (1955).

Results and Discussion

Analysis of variance between generations revealed significance of mean squares due to treatment for all the traits under study except, plant height and moisture content in family II (GAT 5 × 2015/TOLCV RES-1). The interpretation of heritability studies is illustrated below in following heads

1) Days to Flowering: Higher estimates of broad sense heritability were recorded for all the families under study. Whereas, higher estimates of narrow sense heritability wererecorded for family III, V and VI. Higher values of genetic advance were reported for families V and VI.

The higher narrow sense heritability coupled with high genetic advance were reported for family V and VI.The higher narrow sense heritability coupled with high genetic advance were reported for family V and VI.Suggesting, selection for this trait can be fruitful for the improvement of trait under study. Higher estimate of narrow sense heritability along with moderate value of genetic advance indicates presence of strong additive gene action with limited influence of environment. Negative estimates of narrow sense heritability and genetic advance were recorded for family I, II and IV indicating influence nonadditive genes and selection would be effective for the trait in these families. High heritability with higher genetic advance governed by additive genes, thereby it is useful for selection of yield related trait for the improvement. Similar results were also obtained by Thainakul et al. (2017), Saravanan et al. (2018), Singh and Singh (2018) and Anuradha et al. (2020) for the earliness in flowering of tomato.

2) Branches per Plant: The range of broad sense heritability estimates ranged from 8.45 % (family V) to 79.13 % (family II); for narrow sense heritability estimates ranged from 14.16 % (family VI) to 77.89 % (family IV). Higher magnitude of genetic advance was reported forfamily I, III and IV; whereas lower magnitude was reported in family II and VI.Higher estimates of both broad sense and narrow sense heritability along with higher genetic advance was reported for family IV.Higher estimates of both broad sense and narrow sense heritability along with higher genetic advance was reported for family IV. While, high narrow sense heritability with higher genetic advance was reported for family III and IV, revealing importance of additive gene effects. Moderate value of narrow sense heritability with lower genetic advance was reported for family II and IV indicates influence of nonadditive gene effects in governing the character and selection would be less useful for this trait. Lower estimate of broad sense heritability along with negative narrow sense heritability and genetic advance indicates higher influence of environment and/or lack of assumption i.e., presence of epistatis. Similar findings of high heritability along with high genetic advance were reported by Singh et al. (2015), Thainakul et al. (2017), Meena et al. (2018), Anuradha et al. (2020). While, lower genetic advance was reported by Saravaran et al. (2019).

3) Plant Height: The higher estimates of broad sense heritability were reported for family I, III and IV indicating the variation accounted due to genetic attributes, while estimates ranged from 38.48 % (family II) to 72.77 % (family VI). Negative values of broad sense heritability were reported for family IV and V, suggesting higher influence of environment in these families. Higher magnitude of narrow sense heritability along with higher genetic advance was reported for II and III. Higher magnitude of narrow sense heritability along with higher genetic advance was reported for II and III. While, lower values of narrow sense heritability along with lower magnitude of genetic advance was reported in family II and VI. Negative estimates of narrow sense heritability and genetic advance indicate role of environment effects in governing the trait. Selection in families having higher estimates of heritability along with moderate to high genetic advance would be rewarding as this will be more responsive. High heritability coupled with high genetic advance was also reported by Reddy et al. (2013), Singh et al. (2015), Doddamani et al. (2017) Thainakul et al. (2017), Meena et al. (2018), Saravanan et al. (2018), Anuradha et al. (2020) Kumar and Yadav (2021). While, low narrow sense heritability was reported by Chi (2017) as reported for families II and VI.

4) Fruit Length: The estimates of broad sense heritability ranged from 3.42 % (family IV) to 79.15 % (family VI). Family IV and I had low heritability; whereas family III exhibited negative estimate of broad sense heritability. Family III, IV and V possessed higher estimates of narrow sense heritability coupled with high genetic advance, revealing potential scope of selection in further generations. Family V had higher estimates of both heritability i.e. broad sense and narrow sense, indicating potential response towards selection. Similar findings with higher heritability for this trait were reported by Reddy et al. (2013) and Mawasid et al. (2019).

5) Fruit Girth: The estimates of broad sense heritability, narrow sense heritability and genetic advance for fruit girth ranged from 7.99 to 91.76 %, 43.12 to 149.05 % and 20.45 to 89.47 %, respectively. Higher estimates of broad sense heritability, narrow sense heritability and genetic advance were reported for family III, IV and VI, and high narrow sense heritability and high heritability in family I, revealing strong influence ofadditive gene effects. This can be harnessed by selection in further generations in order to improve this character directly. For family II, negative estimates of narrow sense heritability along with high estimates of broad sense heritability indicating strong influence of environment. Similar findings were reported by Kaushik and Dhaliwal (2018) and Damor (2021) who reported high heritability for the character.

6) Average Fruit Weight: Higher estimates of broad sense heritability, narrow sense heritability and genetic advance were recorded for family I, V and VI; whereas higher estimates of narrow sense heritability coupled with high genetic advance was reported for family IV, suggesting role of additive gene action for the average fruit weight. Negative estimate of broad sense heritability was recorded for family IV. Lower estimates of broad sense heritability were recorded for family III and V. While, negative estimates of narrow sense heritability with negative genetic gain exhibited by family II and III. The results were in accordance with previous findings of Patel et al. (2013), Reddy et al. (2013), Singh et al. (2015), Doddamani et al. (2017), Thainakul et al. (2017), Kaushik and Dhaliwal (2018), Meena et al. (2018), Saravanan et al. (2018), Singh and Singh (2018), Mawasid et al. (2019), Anuradha et al. (2020), Kumar and Srivastava (2021) and Kumar and Yadav (2021).

7) Pericarp Thickness: The higher broad sense heritability estimates were observed for family I (51.18 %), with higher magnitude of narrow sense heritability (76.91 %) combined with higher values of genetic advance as percent of mean (31.99 %) which offers the greatest chance for improvement through simple selection method. However, family II (49.2 %) and family IV (27.64 %) exhibited moderate estimates of broad sense heritability for fruit girth. In addition to this, family I, II, III and family V exhibited higher values of narrow sense heritability with higher genetic advance, was a positive indication of presence of additive gene action and suggests selection methods for improvement of this trait. Moderate to higher values of broad sense heritability reported for all the families under study. Estimates of broad sense heritability ranged from 43.84 %(family II) to 55.23 (family VI). While, estimates of narrow sense heritability ranged from18.77 %(family VI) to 81.28 % (family II), with negative values for two families (family I and III). Moderate narrow sense heritability with low genetic advance was recorded for family III and VI; whereas higher narrow sense heritability along with moderate genetic advance was recorded for family V. Both of these reveal importance of nonadditive gene effects and suggest improvement in this character will be slower. Alternate approaches like recurrent selection and mating among individuals in advanced generations can be practiced to improve the character further. High narrow sense heritability with high genetic gain was recorded for family II. The present findings are in partial agreement with the findings of Kaushik and Dhaliwal (2018) and Meena et al. (2018).

8) Fruit Yield per Plant: Four out ofsix families recorded positive estimates of broad sense heritability for fruit yield per plant. Among positive values, estimates of broad sense heritability ranged from 3.13 % (family I) to 72.44 % (family II). Moderate to higher estimates of narrow sense heritability and higher estimates of genetic gain recorded for four families. While, two families had negative values of narrow sense heritability.Presence of high narrow sense heritability coupled with high genetic gain indicates scope of improvement for this character by selection method. Negative values of genetic advance indicating influence of environmental factors, which is reported for two families(family II and IV). Similar outcomes are recorded fruit yield per plant investigations of tomato crop by Patel et al. (2013), Reddy et al. (2013), Singh et al. (2015), Kaushik and Dhaliwal (2018), Meena et al. (2018), Saravanan et al. (2018), Singh and Singh (2018), Mawasid et al. (2019), Anuradha et al. (2020), Kumar and Srivastava (2021), Kumar and Yadav (2021).

9) Locules per Fruit: Moderate to higher magnitude of broad sense heritability wererecorded for all the families under study, except for family III, in which, it had negative value. Higher values of narrow sense heritability and genetic advancewere recorded for all families, except family III. Total five out of six families possessed high estimates of narrow sense heritability and genetic advance. Families V and VI exhibited moderate values of broad sense heritability but high values for narrow sense heritability and genetic gain. Higher estimates of heritability (i.e., broad sense and narrow sense) coupled with high genetic gain indicates huge part of additive gene action governing the character, which is fixable. Selection for this character will be worthy and improvement will be quick. The findings were in accordance with Singh et al. (2015), Kaushik and Dhaliwal (2018), Saravanan et al. (2018), Singh and Singh (2018) and Saravaran et al. (2019).

10) Lycopene Content: The values of broad sense heritability were reported higher for all the families under study for lycopene content. Estimates of narrow sense heritability and genetic advance reported higher in all families except family V, in which estimates of narrow sense heritability and genetic advance was negative. Higher estimates of heritability along high genetic gain indicates possible improvement of the character by selection. Apart from that, it also suggests that character is least affected by environmental factors. Higher heritability along with high genetic gain indicates involvement of additive i.e., fixable gene effect and can be harnessed by proper selection. Similar findings with higher heritability and geneticgain were reported by Doddamani et al. (2017), Kumar and Srivastava (2017), Kaushik and Dhaliwal (2018) and Anuradha et al. (2020)

11) Total Soluble Solids: Higher values of broad sense heritability were observed for total soluble solids in all the families under study, indicating less influence of environmental variation in governing the trait. Estimates of broad sense heritability ranged from 67.21 % (family III) to 84.43 % (family IV). Whereas, estimates of narrow sense heritabilitywerereported negative for family III and moderate to higher inall other families. Values of genetic advance reported negative for family III and lower to higher in the remaining families. Moderate values of narrow sense heritability coupled with lower genetic gain were reported for families II, V and VI, indicating influence non-additive gene action in governing trait. To utilize these non-additive gene effects heterosis breeding should be practiced. While, higher estimates of narrow sense heritability coupled with higher genetic advance exhibited by family I and III which in turn states that presence of greater amount of additive gene action with low environmental effect indicated wider opportunity to improve this trait via selection methods. The present outcomes were partially in accordance with the findings of Singh et al. (2015) who also reported high heritability coupled with high genetic gain for the character.

12) Moisture Content: The values of broad sense heritability for moisture content were negative for family I, II and III, 24.17 % for family V, 60.11 % for family VI and 80.16 % for family IV. While, estimates of narrow sense heritability were higher for family II, III and III and negative for families I, IV and V. While, values of genetic gain were lower in magnitude for three families viz., II, III and VI, while negative values were reported for families I, IV and V. Since, cultivars with lower moisture content are preferable, plant bearing fruits with lower moisture content should be favored during process of selection among individuals.

13) 1000 Seed Weight: Estimates of broad sense ranged from 3.66 % (family IV) to 78.69 % (family III) and lower values were reported for family II (5.43%) and IV (3.66%). In other families viz. I, III, IV and V higher values of broad sense heritability were recorded indicating greater role of genetic variation than environmental effect in governing the trait. Values of narrow sense heritability were high for all the families except, family VI. Negative genetic advance was reported for family VI and moderate for family I, respectively. While, family II, III and IV exhibited higher values of narrow sense heritability and genetic advance indicating predominant role of additive gene effect i.e., fixable and can be utilized by selection procedures. The present results are supported by the results of Doddamani et al. (2017).

14) Seed to Pulp Ratio: Estimates of broad sense heritability were moderate to higher for Seed to pulp ratio and values ranged from 30.37 % (family I) to 71.49 % (family VI) indicating less influence of environmental factors in governing the trait. While, values of narrow sense heritability were higher for allthe families except, for family I in which value of narrow sense heritability and genetic advance were reported negative. Moderate genetic gain coupled with high heritability recorded for family II. In family III, IV, V and VI high values of narrow sense heritability coupled with high genetic advance recorded indicating preponderance of additive gene effects which are fixable. Improvement can be made by simple selection methods.

Conclusion

Highest estimates of broad sense heritability were recorded for lycopene content (98.02%) for family I, followed by fruit girth (91.76%) for family III and lycopene content (90.91%)for family IV. Highest value of narrow sense heritability was recorded for lycopene content (181.26%) in family I, followed by days to flowering (159.81%) for family I and fruit girth (149.05%) for family III. Values of expected genetic advance were reported highest for lycopene content (452.67%) for family I, (212.85%) for family III, 1000 seed weight for family V.

Based on the present findings, it can be concluded that improvement of yield and associated traits to tomato (*L. esculentum*)should be focused on character basis and requirement of breeding programs. However,the inheritance of the studied traits followed complex inheritance, it is further necessary to validate and examine the higher order interactions of genes involved for various traits exhibited by the *L. esculentum*.

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Table 1: Estimates of heritability (Broad-sense and narrow sense) and expected genetic advance (% of mean) for characters under study

Family	Heritability (Broad sense) (%)	Heritability Narrow sense) (%)	Expected Genetic advance (% of mean)
Days to flowering			
I	67.13	-	-
II	54.59	-	-
III	61.31	58.59	14.74
IV	88.12	-	-
V	61.92	159.81	43.38
VI	62.85	119.64	36.36
Branches per plant			
I	44.54	49.03	24.57
II	79.13	15.95	6.64
III	46.19	51.13	26.41
IV	65.80	77.89	35.49
V	8.45	-	-
VI	65.20	14.16	3.65
Plant height			
I	55.56	8.92	5.84
II	38.48	74.16	34.42
III	58.87	63.79	28.77
IV	-	3.26	1.33
V	-	-	-
VI	72.77	-	-
Fruit length			
I	26.94	-	-
II	78.57	-	-
III	-	105.17	48.35
IV	3.42	149.02	77.69
V	54.23	93.28	41.31
VI	79.15	-	-
Fruit girth			
I	7.99	61.19	24.97
II	71.81	-	-
III	91.76	149.05	89.47
IV	89.71	43.12	26.15

V	77.43	45.73	20.45
VI	28.82	128.50	77.95

Cont.

Family	Heritability (Broad sense) (%)	Heritability Narrow sense) (%)	Expected Genetic advance (% of mean)
Average fruit weight			
I	59.19	77.55	28.02
II	72.95	-	-
III	28.53	-	-
IV	-	124.79	71.55
V	31.58	133.48	86.62
VI	72.19	133.96	74.60
Pericarp thickness			
I	49.98	-	-
II	43.84	81.28	36.05
III	51.63	25.93	9.44
IV	50.75	-	-
V	51.16	49.01	18.21
VI	55.23	18.77	9.96
Fruit yield per plant			
I	3.13	36.88	54.17
II	72.44	-	-
III	62.23	16.20	23.49
IV	-	-	-
V	-	36.93	34.51
VI	29.87	34.80	46.54
Locules per fruit			
I	67.02	148.80	140.58
II	48.86	63.80	44.54
III	-	-	-
IV	85.10	102.75	62.76
V	36.48	63.49	45.61
VI	36.87	70.49	40.82
Lycopene content			
I	98.02	181.26	452.67
II	89.73	70.88	42.60

III	78.60	129.32	212.85
IV	90.91	128.31	130.05
V	70.98	-	-
VI	66.70	141.86	82.54

Cont.

Family	Heritability (Broad sense) (%)	Heritability Narrow sense) (%)	Expected Genetic advance (% of mean)
Total soluble solid			
I	71.32	100.47	26.18
II	80.45	24.03	7.86
III	67.21	-	-
IV	84.43	105.11	47.96
V	72.44	21.73	7.08
VI	74.58	23.97	9.11
Moisture content			
I	-	-	-
II	-	61.73	6.69
III	-	71.35	5.71
IV	80.16	-	-
V	24.17	-	-
VI	60.11	62.46	5.31
1000 seed weight			
I	74.19	32.81	19.88
II	5.43	88.95	54.85
III	78.69	63.47	36.25
IV	70.51	108.70	93.86
V	69.54	143.39	145.14
VI	3.66	-	-
Seed to pulp ratio			
I	30.37	-	-
II	65.47	36.40	11.98
III	66.70	64.21	38.81
IV	63.16	98.80	61.77
V	59.89	107.54	58.69
VI	71.49	35.65	20.94

Note:'-' indicates negative values for particular character.